

PHYSICS NUMERICAL QUESTION

Unit 1: Rotational Dynamics and Oscillatory Motion

Example:

Example 8-1

A balance scale consisting of a weightless rod has a mass of 0.1 kg on the right side 0.2 m from the pivot point. See Fig. 8-2. (a) How far from the pivot point on the left must 0.4 kg be placed so that a balance is achieved? (b) If the 0.4-kg mass is suddenly removed, what is the instantaneous rotational acceleration of the rod? (c) What is the instantaneous tangential acceleration of the 0.1-kg mass when the 0.4-kg mass is removed?

Example 8-2

A large wheel of radius 0.4 m and moment of inertia 1.2 kg-m^2 , pivoted at the center, is free to rotate without friction. A rope is wound around it and a 2-kg weight is attached to the rope (see Fig. 8-4). When the weight has descended 1.5 m from its starting position (a) what is its downward velocity? (b) what is the rotational velocity of the wheel?

Example 8-4

Suppose the body of an ice skater has a moment of inertia $I = 4 \text{ kg-m}^2$ and her arms have a mass of 5 kg each with the center of mass at 0.4 m from her body. She starts to turn at 0.5 rev/sec on the point of her skate with her arms outstretched. She then pulls her arms inward so that their center of mass is at the axis of her body, $r = 0$. What will be her speed of rotation?

Example 10-2

A given spring stretches 0.1 m when a force of 20 N pulls on it. A 2-kg block attached to it on a frictionless surface as in Fig. 10-4 is pulled to the right 0.2 m and released .. (a) What is the frequency of oscillation of the block? (b) What is its velocity at the midpoint? (c) What is its acceleration at either end? (d) What are the velocity and acceleration when $x = 0.12 \text{ m}$, on the block's first passing this point?

Example 10-3

The block of Example 10-2 is released from a position of $X_1 = A = 0.2$ m as before.

(a) What is its velocity at $X_2 = 0.1$ m? (b) What is its acceleration at this position?

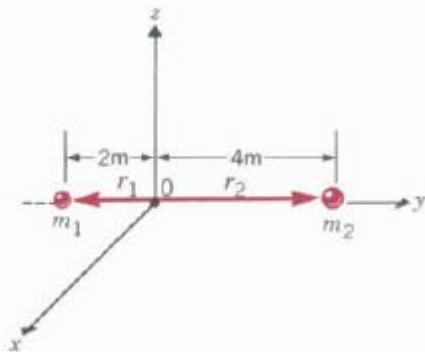
Problems

8.1 A bicycle wheel of mass 2 kg and radius 0.32 m is spinning freely on its axle at 2 rev/sec. When you place your hand against the tire the wheel decelerates uniformly and comes to a stop in 8 sec. What was the torque of your hand against the wheel?

8.2 Two masses, $m_1 = 1$ kg and $m_2 = 5$ kg, are connected by a rigid rod of negligible weight (see Fig. 8-6). The system is pivoted about point O. The gravitational forces act in the negative z direction.

(a) Express the position vectors and the forces on the masses in terms of unit vectors and calculate the torque on the system.

(b) What is the angular acceleration of the system at the instant shown in Fig.8.6?



8.7 A uniform wooden board of mass 20 kg rests on two supports as shown in Fig. 8-9. A 30-kg steel block is placed to the right of support A. How far to the right of A can the steel block be placed without tipping the board? (Answer . 2.0 m.)

8.18 A children's merry-go-round of radius 4 m and mass 100 kg has an 80-kg man standing at the rim. The merry-go-round coasts on a frictionless bearing at 0.2 rev/sec. The man walks inward 2 m toward the center. What is the new rotational speed of the merry-go-round? What is the source of this energy? (The moment of inertia of a solid disk is $I = \frac{1}{2} mr^2$).
(Answer: 0.37 rev/sec.)

10.5 An oscillating block of mass 250 g takes 0.15 sec to move between the endpoints of the motion, which are 40 cm apart. (a) What is the frequency of the motion? (b) What is the amplitude of the motion? (c) What is the force constant of the spring?

10.13 A block is oscillating with an amplitude of 20 cm. The spring constant is 150 N/m. (a) What is the energy of the system? (b) When the displacement is 5 cm, what is the kinetic energy of the block and the potential energy of the spring?

10.18 A spring ($k = 200 \text{ N/m}$) is compressed 10 cm between two blocks of mass $m_1 = 1.5 \text{ kg}$ and $m_2 = 4.5 \text{ kg}$ (see Fig. 10-12). The spring is not connected to the blocks, and the table is frictionless. What are the velocities of the blocks after they are released and lose contact with the spring? Assume that the spring falls straight down to the table.

Note: Reference C [in micro syllabus] is preferred for additional numerical

Unit 2. Electric and Magnetic Field

Examples:

Example 14-1

A charge $q_1 = 3 \times 10^{-6} \text{ C}$ is located at the origin of the x axis. A second charge $q_2 = -5 \times 10^{-6} \text{ C}$ is also on the x axis 4 m from the origin in the positive x direction. (a) Calculate the electric field at the midpoint P of the line joining the two charges. (b) At what point P' on that line is the resultant field zero?

Example 14-2

Three charges- $q_1 = 3 \times 10^{-6} \text{ C}$, $q_2 = -5 \times 10^{-6} \text{ C}$, and $q_3 = -8 \times 10^{-6} \text{ C}$ -are positioned on a straight line as shown in Fig. 14-6. Find the potential energy of the charges.

Example 16-1

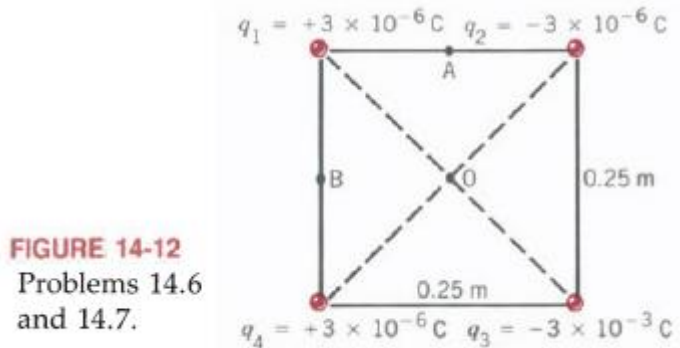
Assume that the electron in a hydrogen atom is essentially in a circular orbit of radius $0.5 \times 10^{-10} \text{ m}$, and rotates about the nucleus at the rate of 10^{14} times per second. What is the magnetic moment of the hydrogen atom due to the orbital motion of the electron?

Example 16-2

A current of 50 A is established in a slab of copper 0.5 cm thick and 2 cm wide. The slab is placed in a magnetic field B of 1.5 T. The magnetic field is perpendicular to the plane of the slab and to the current. The free electron concentration in copper is $8.4 \times 10^{28} \text{ electrons/m}^3$. What will be the magnitude of the Hall voltage across the width of the slab?

Problems:

14.6 Four charges of equal magnitude are placed at the corners of a square as shown in Fig. 14-12. What is the electric field at the center of the square, point O?



14.8 Two large parallel plates are separated by a distance of 5 cm. The plates have equal but opposite charges that create an electric field in the region between the plates. An O' particle ($q = 3.2 \times 10^{-19} \text{ C}$, $m = 6.68 \times 10^{-27} \text{ kg}$) is released from the positively charged plate, and it strikes the negatively charged plate $2 \times 10^{-6} \text{ sec}$ later. Assuming that the electric field between the plates is uniform and perpendicular to the plates, what is the strength of the electric field?
(Answer: 522 N/C.)

14.21 An electron is placed midway between two fixed charges, $q_1 = 2.5 \times 10^{-10} \text{ C}$ and $q_2 = 5 \times 10^{-10} \text{ C}$. If the charges are 1 m apart, what is the velocity of the electron when it reaches a point 10 cm from q_2 ?

16.1 What force is experienced by a wire of length $l = 0.08 \text{ m}$ at an angle of 20° to the magnetic field direction carrying a current of 2 A in a magnetic field of 1.4 T?

16.2 The earth's magnetic field at the equator is $4 \times 10^{-5} \text{ T}$ and is parallel to the surface of the earth in the south-north direction. (Note that the earth's geographic north pole is the magnetic south pole.) A wire 2 m long of mass $m = 9 \text{ g}$ is suspended by a string. The wire is also parallel to the earth's surface and carries a current of 150 A in the east-west direction. (a) What is the tension on the string?
(b) What would be the tension if the current was in the west-east direction?
(Answer: (a) $10.02 \times 10^{-2} \text{ N}$, (b) $7.62 \times 10^{-2} \text{ N}$.)

16.12 A proton is moving with a velocity $\mathbf{v} = (3 \times 10^5 \mathbf{i} + 7 \times 10^5 \mathbf{k}) \text{ m/s}$ in a region where there is a magnetic field $\mathbf{B} = 0.4 \mathbf{j} \text{ T}$. What is the force experienced by the proton?
(Answer: $(1.92 \mathbf{k} - 4.48 \mathbf{j}) \times 10^{-14} \text{ N}$.)

16.13 A proton is accelerated through a potential difference of 200 V. It then enters a region where there is a magnetic field $B = 0.5 \text{ T}$. The magnetic field is perpendicular to the direction of motion of the proton. What is the force experienced by the proton?

Note: Reference C [in micro syllabus] is preferred for additional numerical

Unit 3: Fundamentals of Atomic Theory

Examples:

Example 18-2

After being excited, the electron of a hydrogen atom eventually falls back to the ground state. This can take place in one jump or in a series of jumps, the electron falling into lower excited states before it ends up in the ground state. Consider a hydrogen atom that has been raised to the second excited state, that is, $n = 3$. Calculate the different photon energies that may be emitted as the atom returns to the ground state.

Example 19-1

A beam of monochromatic neutrons is incident on a KCl crystal with lattice spacing of 3.14 Å. The first-order diffraction maximum is observed when the angle (θ) between the incident beam and the atomic planes is 37° . What is the kinetic energy of the neutrons?

Problems:

18.1 Calculate the shortest and the longest wavelength of the Balmer series of hydrogen.

18.2 What are (a) the energy, (b) the momentum, and (c) the wavelength of the photon that is emitted when a hydrogen atom undergoes a transition from the state $n = 3$ to $n = 1$? (The momentum of the photon is given by $h\nu/c$).

(Answer: (a) 12.07 eV, (b) $6.44 \times 10^{-27} \text{ kg-m/sec}$, (c) 1030 Å.)

18.3 The shortest wavelength of the Paschen series from hydrogen is 8204 Å. From this fact, calculate the Rydberg constant.

18.19 The ground-state and the first excited-state energies of potassium atoms are -4.3 eV and -2.7 eV, respectively. If we use potassium vapor in the Franck-Hertz experiment, at what voltages would we see drops in the plot of current versus voltage?

19.2 The de Broglie wavelength of a proton is 10^{-13} m. (a) What is the speed of the proton? (b) Through what potential difference must the proton be accelerated to acquire such a speed?

19.7 An α particle is emitted from a nucleus with an energy of 5 MeV (5×10^6 eV). Calculate the wavelength of an α particle with such energy and compare it with the size of the emitting nucleus that has a radius of 8×10^{-15} m.
(Answer: 6.4×10^{-15} m.)

19.11 In neutron spectroscopy a beam of monoenergetic neutrons is obtained by reflecting reactor neutrons from a beryllium crystal. If the separation between the atomic planes of the beryllium crystal is 0.732 Å, what is the angle between the incident neutron beam and the atomic planes that will yield a monochromatic beam of neutrons of wavelength 0.1 Å?
(Answer: 3.9° .)

19.16 A small particle of mass 10^{-6} g moves along the x axis; its speed is uncertain by 10^{-6} m/sec. (a) What is the uncertainty in the x coordinate of the particle? (b) Repeat the calculation for an electron assuming that the uncertainty in its velocity is also 10^{-6} m/sec. (Answer: (a) 1.05×10^{-19} m, (b) 115 m.)

19.19 The uncertainty in the position of a particle is equal to the de Broglie wavelength of the particle. Calculate the uncertainty in the velocity of the particle in terms of the velocity of the de Broglie wave associated with the particle.
(Answer: V_{wave}/π .)

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Unit 4: Methods of Quantum Mechanics

Examples:

Example 20-2 Probability Calculations

Consider a particle in the ground state, that is, one represented by the wavefunction:

$$\psi_1(x, t) = \chi_1(x)\Gamma(t) = B \sin\left(\frac{\pi x}{a}\right) \exp\left(-\frac{iE_0}{\hbar} t\right)$$

What is (a) the average position, (b) the average momentum, and (c) the average energy of such a particle?

Example 21-2

A beam of hydrogen atoms is used in a Stern-Gerlach type experiment. The atoms emerge from the oven with a velocity $v = 10^4$ m/sec. They enter a region 20 cm long where there is a magnetic field gradient $dB/dz = 3 \times 10^4$ T/m. The field gradient is perpendicular to the incident velocity of the atoms. The mass of the hydrogen atom is 1.67×10^{-27} kg. What is the separation of the two components of the beam as they emerge from the magnet?

Problems:

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} = i\hbar \frac{\partial \psi}{\partial t} \quad (20.3)$$

20.1 Show by direct substitution into the time-dependent Schrodinger equation for the free particle, Eq. 20.3, that $\psi(x, t) = A \cos(kx - \omega t)$ is not a solution.

20.2 Show by direct substitution that the wave function $\psi(x, t) = A \cos kx e^{-i\omega t}$ satisfies the time dependent Schrodinger equation for the free particle, Eq. 20.3.

20.3 Explain why the following eigen functions are not acceptable solutions of the Schrodinger equation

- (a) $\chi(x) = 0$ for $x \leq 0$
 $\chi(x) = A \cos kx$ for $x \geq 0$
- (b) $\chi(x) = A \frac{e^{ikx}}{x}$
- (c) $\chi(x) = A \ln kx$

20.12 What is the probability of finding a particle in a well of width a at a position $a/4$ from the wall if $n = 1$, if $n = 2$, if $n = 3$. Use the normalized wavefunctions

$$\psi(x, t) = (2/a)^{1/2} \sin 2\pi x/a e^{-iE_2 t/\hbar}$$

(Answer: $1/a$, $2/a$, $1/a$.)

21.3 In the Bohr model of the hydrogen atom, the electron is assumed to move in circular orbits around the proton, that is, the motion takes place in a plane that we can call the x-y plane. Use the uncertainty principle in the z direction, that is, $\Delta p_z^2 \Delta z \geq \hbar^2/4$ and the fact that $p_z^2 \geq (\Delta p_z)^2$ (see Problems 19.21 and 19.22) to show that the motion of the electron cannot be planar motion.

21.6 (a) How many atomic states are there in hydrogen with $n = 3$? (b) How are they distributed among the subshells? Label each state with the appropriate set of quantum numbers n, l, m_l, m_s . (c) Show that the number of states in a shell, that is, states having the same n , is given by $2n^2$. (Hint: $1 + 2 + 3 + \dots + n = n(n+1)/2$.)

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Unit 5: Fundamentals of Solid State Physics

Examples:

Example 23-1

Consider a copper wire of cross-sectional area $A = 1 \text{ mm}^2$ carrying a current $i = 1 \text{ amp}$. What is the drift velocity V_d of the electrons? Cu is monovalent, that is, there is one free electron per atom. The density and the molecular weight of Cu are 9 g/cm^3 and 64 g/mole , respectively.

Example 23-2

We showed in Example 23-1 that the number of free electrons in copper is $8.4 \times 10^{28} \text{ electrons/m}^3$. (a) Calculate the Fermi energy for Cu. (b) At what temperature T_f will the average thermal energy $k_B T_f$ of a gas be equal to that energy?

Problems:

22.1 Copper has a face-centered cubic structure with a one-atom basis. The density of copper is 8.96 g/cm^3 and its atomic weight is 63.5 g/mole . What is the length of the unit cube of the structure?

(Answer: 3.61 Å.)

22.3 Assuming that atoms in a crystal structure are arranged as close-packed spheres, what is the ratio of the volume of the atoms to the volume available for the simple cubic structure? Assume a one-atom basis.

(Answer: 0.52)

22.4 Repeat Problem 22.3 for the body-centered cubic structure.

(Answer: 0.68.)

22.5 Repeat Problem 22.3 for the face-centered cubic structure.

(Answer: 0.74.)

22.9 The dissociation energy of the KF molecule is 5.12 eV. The ionization energy for K is 4.34 eV, and the electron affinity of F is 4.07 eV. What is the equilibrium separation constant for the KF molecule?

24.6 The energy gaps of some alkali halides are $\text{KCl} = 7.6 \text{ eV}$, $\text{KBr} = 6.3 \text{ eV}$, $\text{KI} = 5.6 \text{ eV}$. Which of these are transparent to visible light? At what wavelength does each become opaque?

24.8 The density of aluminum is 2.70 g/cm^3 and its molecular weight is 26.98 g/mole . (a) Calculate the Fermi energy. (b) If the experimental value of EF is 12 eV, what is the electron effective mass in aluminum? Aluminum is trivalent.

(Answer: (a) 11.6 eV, (b) $0.97 m$, where m is the free electron mass.)

Note: Reference C [in micro syllabus] is preferred for additional numerical

Unit 6: Semiconductor and Semiconductor Devices

Examples:

Example 25-2

A sample of Si is doped with phosphorous. The donor impurity level lies 0.045 eV below the bottom of the conduction band. At $T = 300$ K, E_F is 0.010 eV above the donor level. Calculate (a) the impurity concentration, (b) the number of ionized impurities, (c) the free electron concentration, and (d) the hole concentration.

(For Si, $E_g = 1.100$ eV, $m_e^* = 0.31 m$, $m_h^* = 0.38 m$).

Problems:

25.1 The band gap in pure germanium is E_g 0.67 eV. (a) Calculate the number of electrons per unit volume in the conduction band at 250 K, 300 K, and at 350 K. (b) Do the same for silicon assuming $E_g = 1.1$ eV. The effective mass of the electrons in germanium is $0.12 m$ and in silicon $0.31 m$, where m is the free electron mass.

25.2 Suppose that the effective mass of holes in a material is four times that of electrons. At what temperature would the Fermi level be shifted by 10% from the middle of the forbidden energy gap? Let $E_g = 1$ eV.
(Answer: 557 K.)

25.3 The energy gap in germanium is 0.67 eV. The electron and the hole effective masses are $0.12 m$ and $0.23 m$, respectively, where m is the free electron mass. Calculate (a) the Fermi energy, (b) the electron density, and (c) the hole density, at $T = 300$ K.
(Answer: (a) 0.348 eV, (b) $4.1 \times 10^{18} \text{ m}^{-3}$, (c) $4.1 \times 10^{18} \text{ m}^{-3}$.)

25.16 The energy gap in silicon is 1.1 eV, whereas in diamond it is 6 eV. What conclusion can you draw about the transparency of the two materials to visible light (4000 Å to 7000 Å)?

26.1 The current through a p - n junction is 1×10^{-8} A when a reverse bias voltage of 10 V is applied across the junction at $T = 300$ K. What will be the current through the diode when a forward bias voltage of (a) 0.1 V, (b) 0.3 V, and (c) 0.5 V is applied?

26.2 In the ideal diode the reverse saturation current should be as small as possible. Considering the fact that E_g for Si is 1.1 eV and E_g for Ge is 0.67 eV, which material is better suited for the fabrication of $p-n$ junction diodes?

26.3 The reverse saturation current of a silicon diode is $i_o = 5 \times 10^{-9}$ A. The voltage across that diode when forward biased is 0.45 V. (a) What is the current through the diode at $T = 27^\circ\text{C}$? (b) If the voltage across the diode is held constant, and we assume that i_o does not change with temperature, what is the current through the diode at $T = 47^\circ\text{C}$?

(Answer: (a) 0.18 A, (b) 0.06 A)

26.4 In Problem 26.3 we assumed that the reverse saturation current i_o remains constant when the temperature changes. (a) Show that this assumption is highly incorrect by calculating i_o at $T = 47^\circ\text{C}$ when $i_o = 5 \times 10^{-9}$ A at 27°C . Assume that the Fermi level on the p side of the junction is 1 eV below the bottom of the conduction band. (b) If the voltage across the forward biased diode is 0.45 V, as in Problem 26.3, what is the current through the diode at $T = 47^\circ\text{C}$?

Answer: (a) 5.6×10^{-8} A, (b) 0.67 A

26.5 The reverse saturation current of a silicon diode doubles when the temperature changes from 27°C to 33°C . What is the position of the Fermi level on the p side of the junction?

Note: Reference C [in micro syllabus] is preferred for additional numerical

Unit 7: Universal Gates and Physics of Integrated Circuits

Problems:

27.1 Make the appropriate truth tables to prove the following distributive law of boolean algebra:

$$A (B + C) = AB + AC$$

27.6 Analyze the circuit shown in Fig. 27-29. Determine the logic function performed by the circuit by making and justifying the appropriate truth table.

(Answer: AND.)

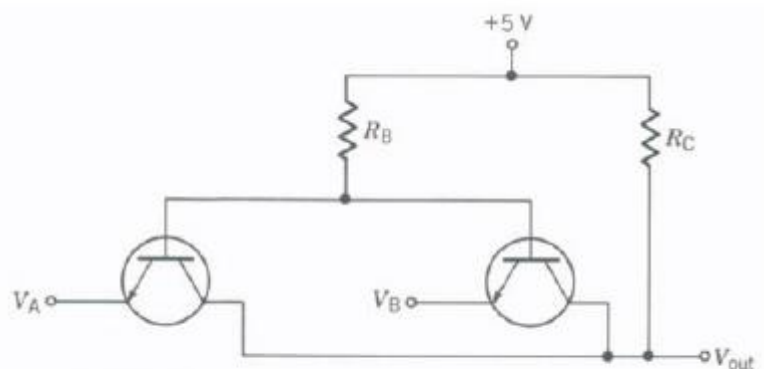


FIGURE 27-29 Problem 27.6.

27.9 (a) Find the truth table for the circuit shown in Fig. 27-31. What logic function does the circuit perform? (b) What logic function will the circuit perform if the constant + 5 V input to the first two gates is changed to ground potential?
(Answer: (a) OR, (b) None.)

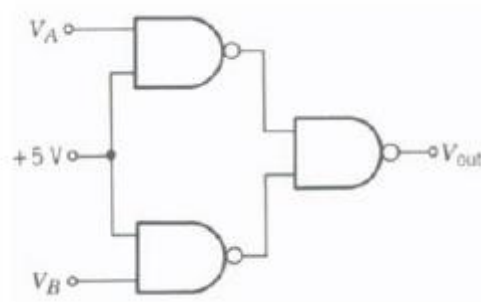


FIGURE 27-31
Problem 27.9.

27.10 (a) Find the truth table for the circuit of Fig. 27-32. What logic function does the circuit perform? (b) What logic function will the circuit perform if the common grounded input to the first two NOR gates is changed to + 5 V?

(Answer: (a) AND, (b) None.)

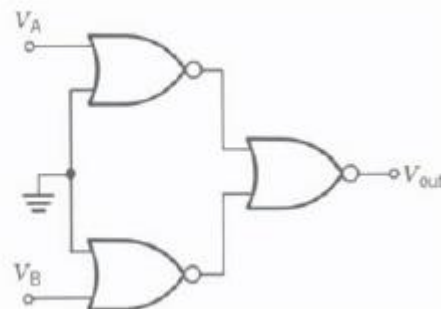


FIGURE 27-32
Problem 27.10.

Note: Reference C [in micro syllabus] is preferred for additional numerical